NASA Advisory Council Aeronautics Committee Report

Ms. Marion Blakey, *Chair*

July 31, 2014
NASA Langley Research Center

National Aeronautics and Space Administration

Committee Information

- **Members:**
  - Ms. Marion Blakey, Chair (Aerospace Industries Association)
  - Mr. John Borghese (Rockwell Collins)
  - Dr. Karen Thole(Penn State University)
  - Dr. John Langford (Aurora Flight Sciences)**
  - Mr. Mark Anderson (Boeing)
  - Dr. John-Paul Clarke (Georgia Institute of Technology)
  - Dr. Mike Francis (UTRC)
  - Dr. Mike Bragg (University of Illinois)
  - Mr. Tommie Wood (Bell Helicopter)
  - Mr. Stephen Morford (Pratt and Whitney)**
- Plans for next meeting: December 4-5, 2014 at Ames Research Center

** Not in Attendance

Areas of Interest Explored at Current Meeting

Topics covered at the Aeronautics Committee meeting held on July 29, 2014 at NASA Langley Research Center:

ARMD Strategic Implementation Plan Progress

Low Carbon Propulsion Strategic Thrust Overview

Advanced Composites Project Review*

Umanned Aircraft Systems (UAS) in the National Airspace System (NAS) Flight Test Planning (NAC Recommendation Update)

National Research Council Autonomy Study Final Report

* These topics have related recommendations or findings provided by the Aeronautics Committee

Strategic Implementation Plan

- The ARMD Strategic Implementation Plan presents the NASA Aeronautics Research Mission Directorate's view of aeronautical research aimed at the next 20 years and beyond, based on:
  – The aviation community's plans and commitments
  – Assessments of what can be accomplished through the application of technology and advanced concepts
  – Familiarity with U.S. and international organizations that will contribute to these technologies
- Reflects the ARMD Analysis Framework hierarchy of Strategic Thrusts, Outcomes, Research Themes, and Technical Challenges
- Expressed in terms of three timeframes:
  – 2015-2025
  – 2025-2035
  – Beyond 2025

ARMD's Planning Framework

NASA's Aeronautical Research Role

Address Research Needs within Three Overarching Areas Affecting Future Aviation

- Mega Driver 1: Global Growth in Demand for High Speed Mobility
- Mega Driver 2: Global Climate Change, Sustainability, and Energy Transition
- Mega Driver 3: Technology Convergence

ARMD's Aeronautical Research Taxonomy

Strategic Thrusts

ARMD Research is Organized into Six Strategic Thrusts

- Strategic Thrust 1: Safe, Efficient Growth in Global Operation
- Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft
- Strategic Thrust 3 Ultra-Efficient Commercial Vehicles
- Strategic Thrust 4: Transition to Low-Carbon Propulsion
- Strategic Thrust 5: Real-Time System Wide Safety Assurance
- Strategic Thrust 6: Assured Autonomy for Aviation Transformation

Outcomes

Outcomes are Defined for Each of Three Time Periods

Near-Term: 2015-2025	Mid-Term: 2025-2035	Far-Term: Beyond 2035

Research Themes

Long-term Research Areas That Will Enable the Outcomes

- Most Outcomes encompass multiple Research Themes

Technical Challenges

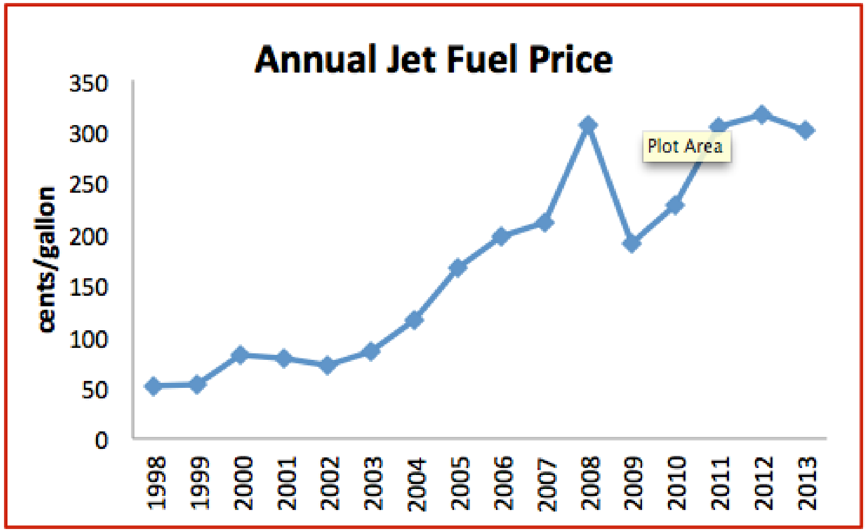
Specific Measurable Research Commitments within the Research Themes

- Most Research Themes encompass several Technical Challenges

Strategic Thrusts and Outcomes

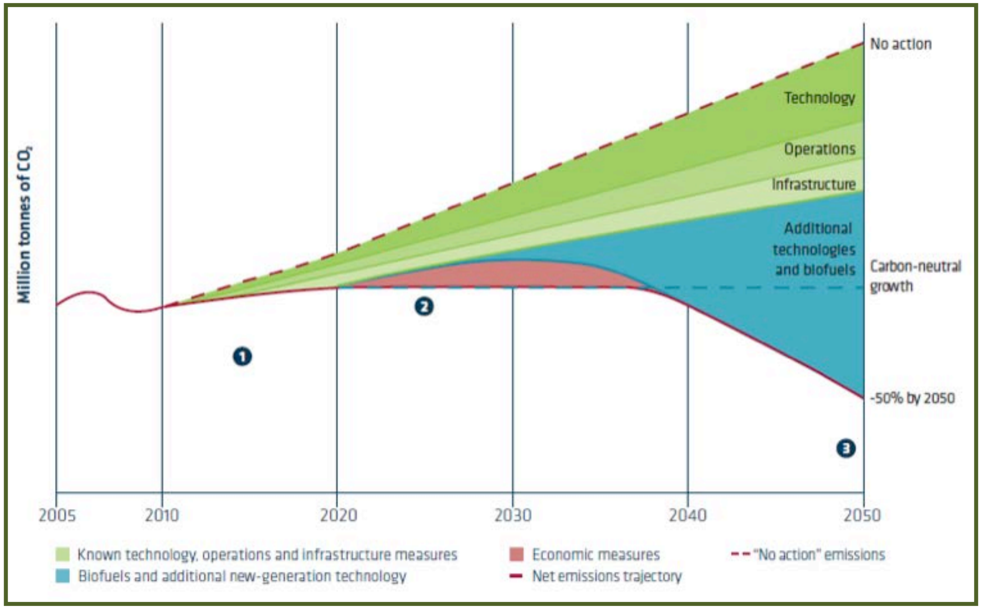
Strategic Thrusts	Outcomes Near-Term (2015-2025)	Outcomes Mid-Term (2025-2035)	Outcomes Far-Term (>2035)
Strategic Thrust 1: Safe, Efficient Growth in Global Operation	2015-2025: Improved Efficiency and Hazard Reduction Within NextGen Operational Domains	2025-2035: System-wide Safety, Predictability, and Reliability Through Full NextGen Functionality	>2035: Flexible, Safe, Scalable Beyond-NextGen System
Strategic Thrust 2: Innovation in Commercial Supersonic Aircraft	2015-2025: Supersonic Overland Certification Standard Based on Acceptable Sonic Boom Noise	2025-2035: Introduction of Affordable, Low-boom, Low-noise, and Low-emission Supersonic Transports	
Strategic Thrust 3: Ultra-Efficient Commercial Vehicles	2015-2025: Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance in 2025	2025-2035: Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035	>2035: Achieve Community Goals for Improved Vehicle Efficiency and Environmental Performance beyond 2035.
		2025-2035: Achieve Community Goals for Improved Vertical Lift Vehicle Efficiency and Environmental Performance in 2035	
Strategic Thrust 4: Transition to Low-Carbon Propulsion	2015-2025: Introduction of Low-carbon Fuels for Conventional Engines and Exploration of Alternative Propulsion Systems	2025:2035: Limited initial introduction of Alternative Propulsion Systems	>2035: Introduction of Alternative Propulsion Systems to Aircraft of All Sizes
Strategic Thrust 5: Real-Time System Wide Safety Assurance	2015:2025: Advanced Safety Assurance Tools Reducing Time-to-Safety-Actions to Days	2025-2035: An Automated Safety Assurance System Enabling Near-real-time System-wide Safety Assurance	>2035: Automated Safety Assurance Integrated with Real-time Operations Enabling a Self-protecting Aviation System
Strategic Thrust 6: Assured Autonomy for Aviation Transformation	2015-2025: Initial Autonomy Applications with Integration of UAS into the NAS	2025-2035: Human-machine Teaming in Key Applications, Such as Single-pilot Operations	>2035: Ability to Fully Certify and Trust Autonomous Systems for Operations in the NAS

Why Low Carbon Propulsion Research?



- ➢ Jet-fuel price volatility
- ➢ Global oil demand growth despite limited production and supply
- ➢ National security threat from foreign energy dependence
- ➢ Aviation environmental impacts estimated at 2% GHG emissions; growth to 3-5% by 2050

- ➢ The aeronautics industry has committed to ambitious GHG reduction goals
- ➢ Aviation energy independence is a key goal of policy makers
- ➢ Aviation alternatives to oil may provide significant economic benefits during the next century



Low-Carbon Propulsion Strategic Thrust

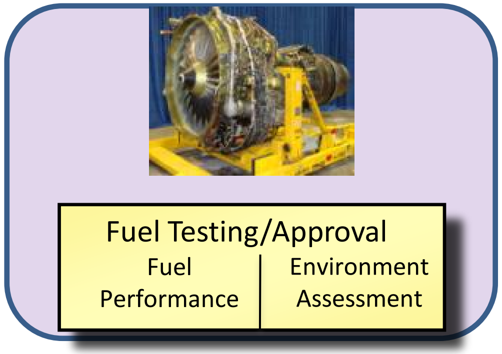
There are two primary focus areas:

1. Characterization of Alternative Fuels

   Example: Fundamental characterization of a representative range of alternative fuel emissions at cruise altitude (to be completed in FY15)

2. Pioneering new Propulsion Concepts / Cycles

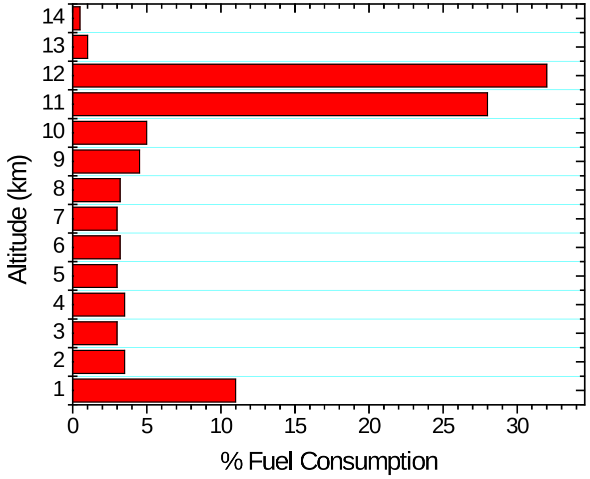
   Example: Achieve a 2 times increase in the power density of an electric motor

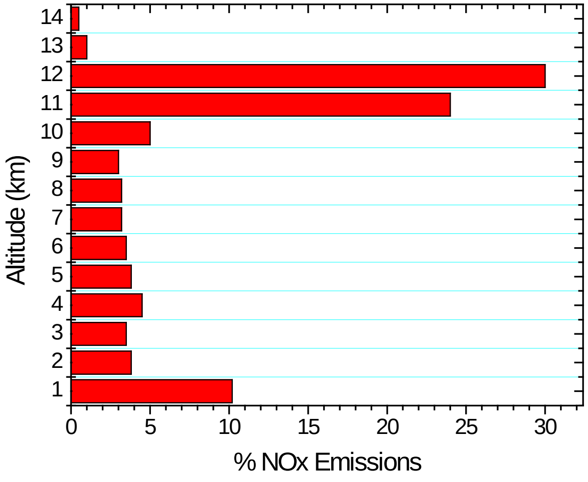


NASA Alternative Jet Fuels Characterization Research

- **Ground-based emissions impact local air quality**
- **Cruise emissions impact climate**

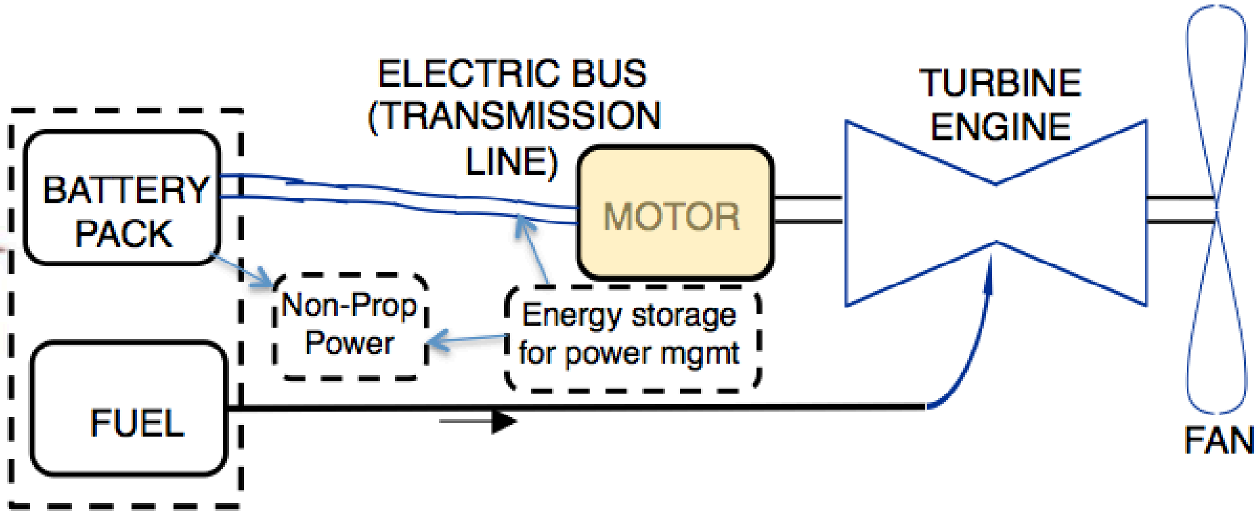
- **Laboratory tests** to determine alternative fuel consumption and emissions characteristics
- **Ground-based engine tests** to evaluate alternative fuel effects on emissions under real-world conditions
- **Cloud chamber tests** to examine PM effects on contrail formation
- **Airborne experiments** to evaluate fuel effects on emissions and contrail formation at cruise
  - o **ACCESS-1: Feb-April, 2013**
  - o **ACCESS-2: May 2014**





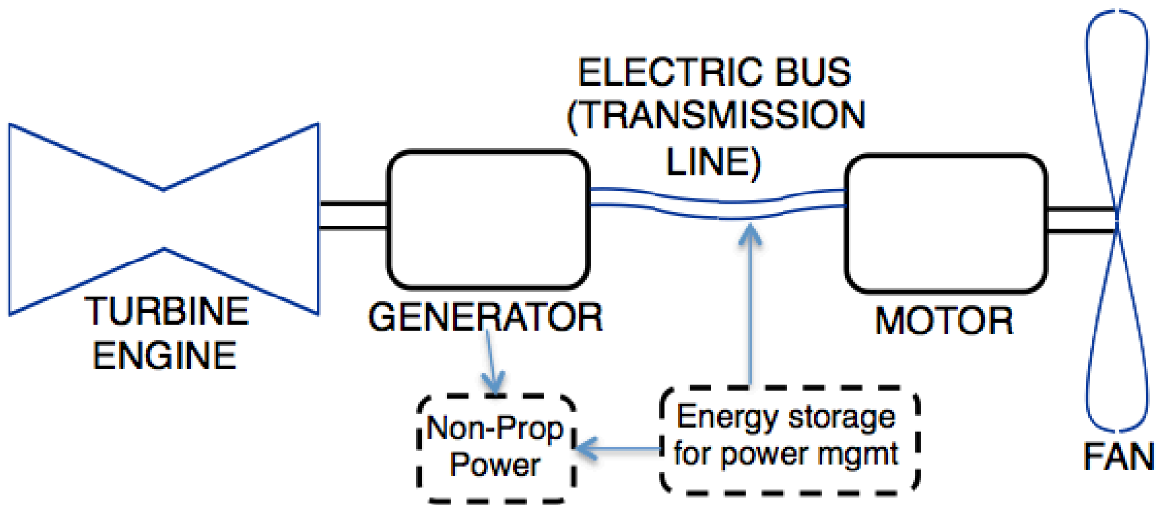
Pioneering New Propulsion Concepts

Hybrid Electric



Both concepts can use either non-cryogenic motors or cryogenic superconducting motors.

Turbo Electric



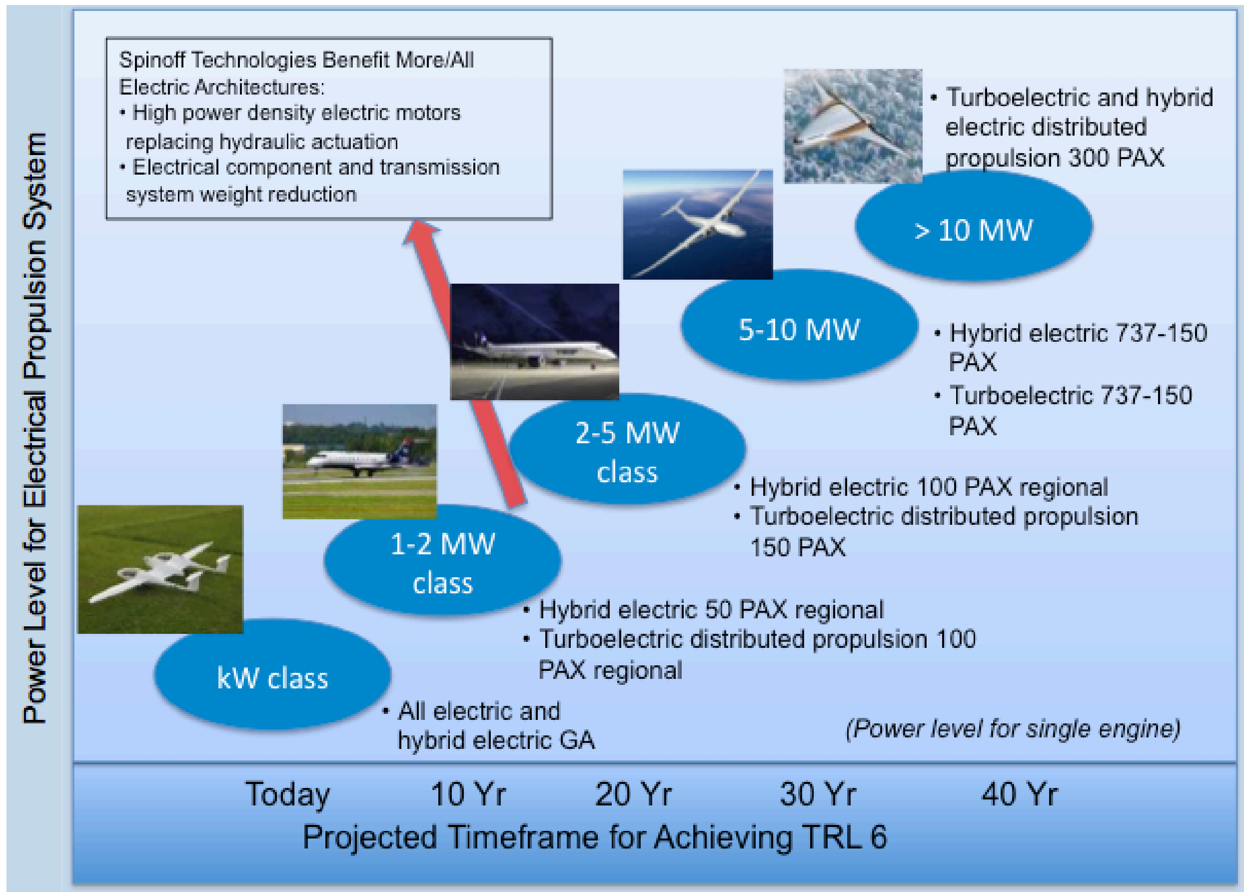
Hybrid Electric Systems for Aviation

Low Carbon Propulsion

NASA studies and industry roadmaps have identified hybrid electric propulsion systems as promising technologies that can help meet national environmental and energy efficiency goals for aviation

Potential Benefits

- Energy usage reduced by more than 60%
- Harmful emissions reduced by more than 90%
- Objectionable noise reduced by more than 65%



Advanced Composites Project

Relevance to National Need

– Focus on reducing the timeline for development and certification of innovative composite materials and structures, which will help American industry retain their global competitive advantage in aircraft manufacturing

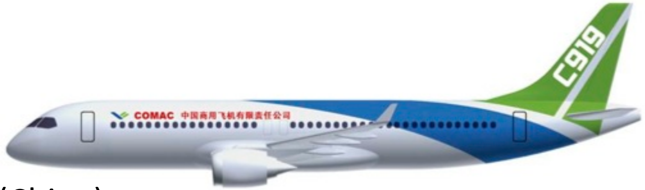
Boeing 787

GE Genx

Lockheed Martin F-35

Northrop Grumman Fire Scout

Airbus A-350 XWB



Comac C919 (China)

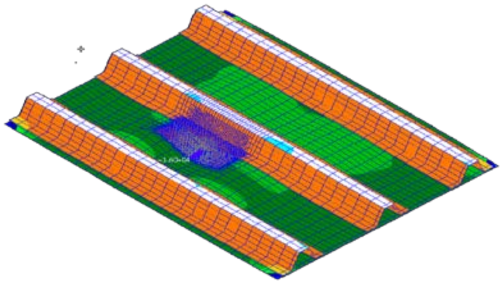
Bombardier C-Series

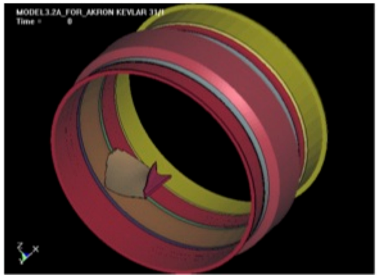
Sukhoi Superjet 100 (Russia)

ACP Technical Challenges

Predictive Capabilities

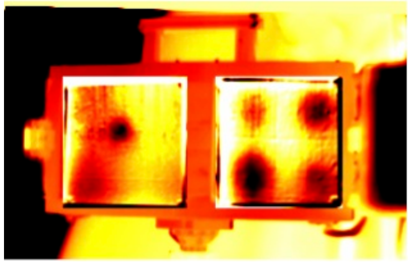
- Robust analysis reducing physical testing
- Better prelim design, fewer redesigns





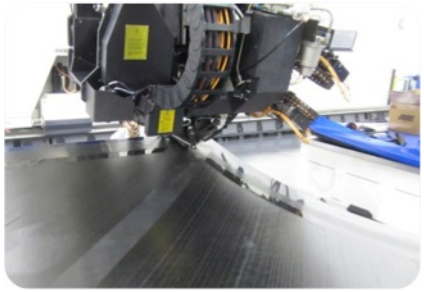
Rapid Inspection

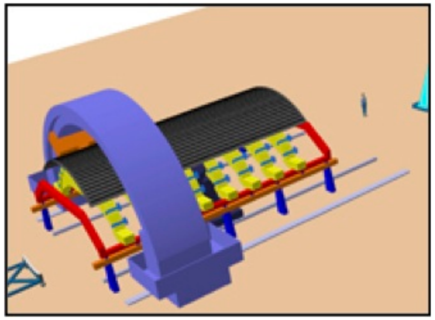
- Increase inspection throughput
- Quantitative characterization of defects
- Automated inspection



Manufacturing Process & Simulation

- Reduce manufacture development time
- Improve quality control
- Fiber placement and cure process models





Project Planning with Partner Input

Portfolio Formulation

Community Needs

1. Material qualification databases
2. Progressive damage modeling
3. Design coupled to manufacturing
4. Bonding and bond qualification
5. Manufacturing tooling and molds
6. Accelerated certification approaches
7. Material durability and aging
8. Education of workforce

- Systems Engineering

Apply Filters

Tech Challenges (v1)

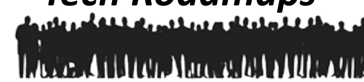
1. Efficient Design
2. Streamlined Certification
3. Progressive Damage Modeling
4. Enhanced Manufacturing
5. Systems Assessment

Vet & Refine

Tech Challenges (v2)

1. Predictive Capability
2. Rapid Inspection
3. Manufacturing Process & Simulation

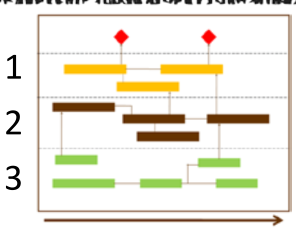
Team Validation & Tech Roadmaps



TC 1

TC 2

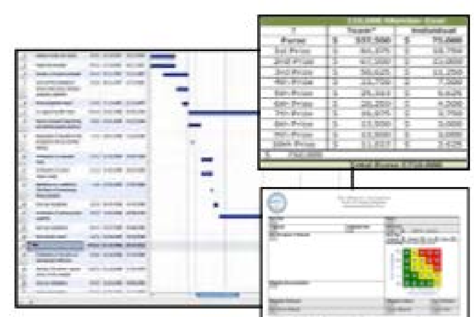
TC 3



- Content, ROM $, time

Phase I Execution

Team-Developed Detailed Technical Work Packages

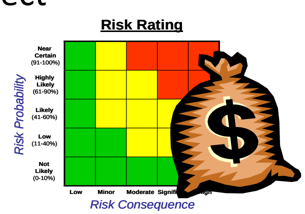


Execute & Evaluate

- Fabricate
- Test
- Analysis
- Timeline model

Manage Portfolio

- Cost/Benefit/Risk Analysis
- Down-select



Role of NASA and Partners

NASA Role

- **Fundamental understanding** of the science and physics
  - Polymer Chemist, Material Scientist, Damage Mechanics, Structural Mechanics
  - Invention of composite raw material forms, processing methods, and fabrication technology
  - Relation of processing parameters to physical measures and material performance
- **High fidelity** analysis and experimental **methods**
- **Independent validation** of methods
- **Coordination** of, and **participation** in, Working Groups

FAA Role

- **Advice** with certification aspects
- **Safety implications** and **practicality** in application

Industry Role

- **Understanding requirements**
  - Common defects and damage
  - Practical operational requirements
  - Experience in application
- **Design and manufacture production quality** characterization and validation **test articles**
- Applied research expertise
- Execution of validation testing and data sets for analysis
- Development of **standard practice for adoption** by industry

Academia Role

- Expertise in **software development:** damage models, process models, data processing
- Formulation and maturation of progressive damage analysis methods

Advanced Composites Consortium (ACC)

- Founding members:
  - NASA, FAA
  - Bell, Boeing, GE Aviation, Lockheed Martin, Northrop Grumman, P&W
- Other members to be added
- 50/50 cost sharing
- Collaborative research tasks with multiple partner teams
- NASA funds through Cooperative Agreement with “Integrator” who administers agreement and dispenses funds through partnering agreements

Executive Steering Committee

Technical Oversight Committee

Cooperative Research Teams

- Shared vision
- Leverage resources
- High gov’t value
- Real issues
- Data / Inventions shared by performing members

Committee Finding for ARMD AA

The Committee believes the Advanced Composites Project is a particularly high value initiative and endorses the approach that NASA ARMD is taking to establish a management and technical plan. The Committee feels that the research goal of reducing the development and certification timeline of composites is an important one that, if successful, will provide benefits to both the aerospace industry and the National economy. The Committee recognizes that there are challenges implementing collaboration aspects of the project (other governmental agencies – FAA and DoD, academia, industry, and the consortium implementation) that breaks new ground but finds that the approach by ARMD is well thought out. The Committee looks forward to continuing to work with ARMD to provide guidance and advice as the project continues to develop.

NAC Recommendation on UAS in the NAS-Demonstration Mission

NASA Advisory Council Recommendation: Unmanned Aircraft Systems in the National Airspace System Project Demonstration Mission [2013-01-02 (AC-01)]:

- **Recommendation:** The NASA Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Project plans as part of their next phase of research a variety of flight tests to validate concepts developed as part of their research. The Council recommends that in addition to these flight tests, one or more “capstone” demonstrations be incorporated into the program plan. These “graduation exercises” should serve to pull together and focus multiple research threads, and provide a compelling test or demonstration that the program’s various stakeholder will find compelling and convincing. The Council encourages NASA to continue working with the UAS Subcommittee in the development of such a capstone demonstration.

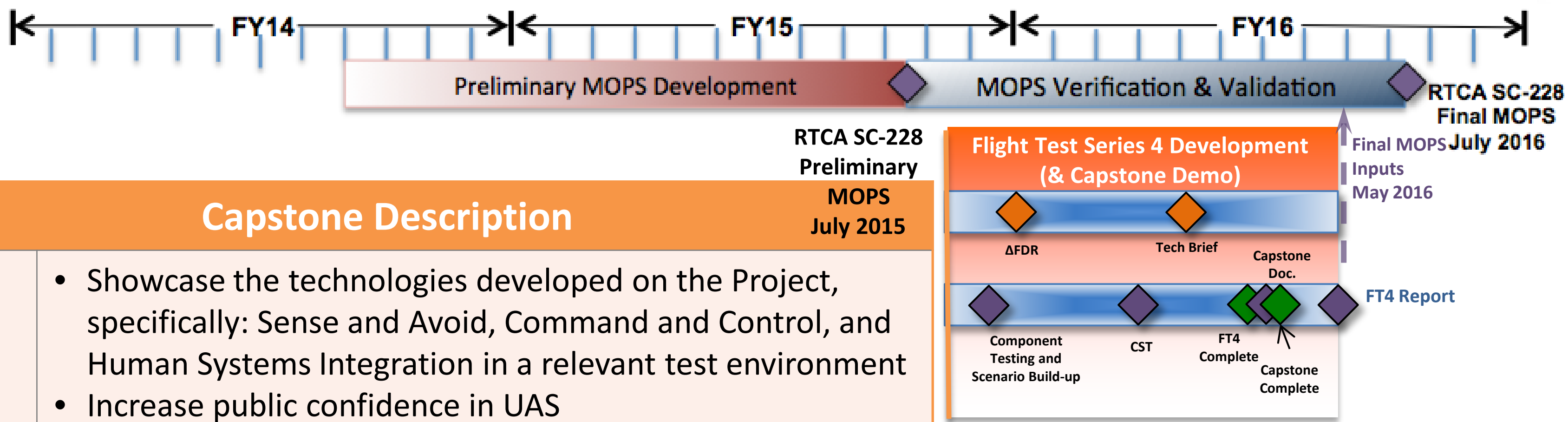
- **Major Reasons for Proposing the Recommendation:** The Council is concerned that sufficient impact is made as a result of the project’s research. These capstone demonstrations would find their way onto the integrated master plan, and would ideally involve both NASA and outside participants, demonstrating the access barriers broken down as a result of the NASA research.

- **Consequences of No Action on the Proposed Recommendation:** Absent compelling capstone events, the various research elements may never achieve the desired synergy.

NAC Recommendation on Autonomy – NASA Response

- *NASA concurs with the recommendation. The UAS Integration in the NAS Project is in the process of designing the Capstone Demonstration to be flown during Phase 2 of the project. This will most likely occur during FY16. The Project presented a summary of progress to date to the NAC Aeronautics Committee's UAS Subcommittee during a briefing at NASA Headquarters on May 21, 2013. The briefing included specific objectives, success criteria, and resource requirements. In addition, the Project presented three candidate Capstone Demonstration scenarios and an assessment of the three candidates against specific phases of flight. An important topic during the Capstone Demonstration discussion was related to whether the Demonstration should be flown in restricted airspace or in the National Airspace System. This is a key question to be answered that affects the pathway forward to get approval to actually fly the Demonstration and will be addressed as we continue to evaluate each of the various scenarios. The Project will look at a variety of pros and cons for each scenario including high-level evaluation of objective satisfaction, cost, benefit and risk. The Project will follow up with a briefing to the Subcommittee currently scheduled for mid-July with a definitive proposal to the Subcommittee.*

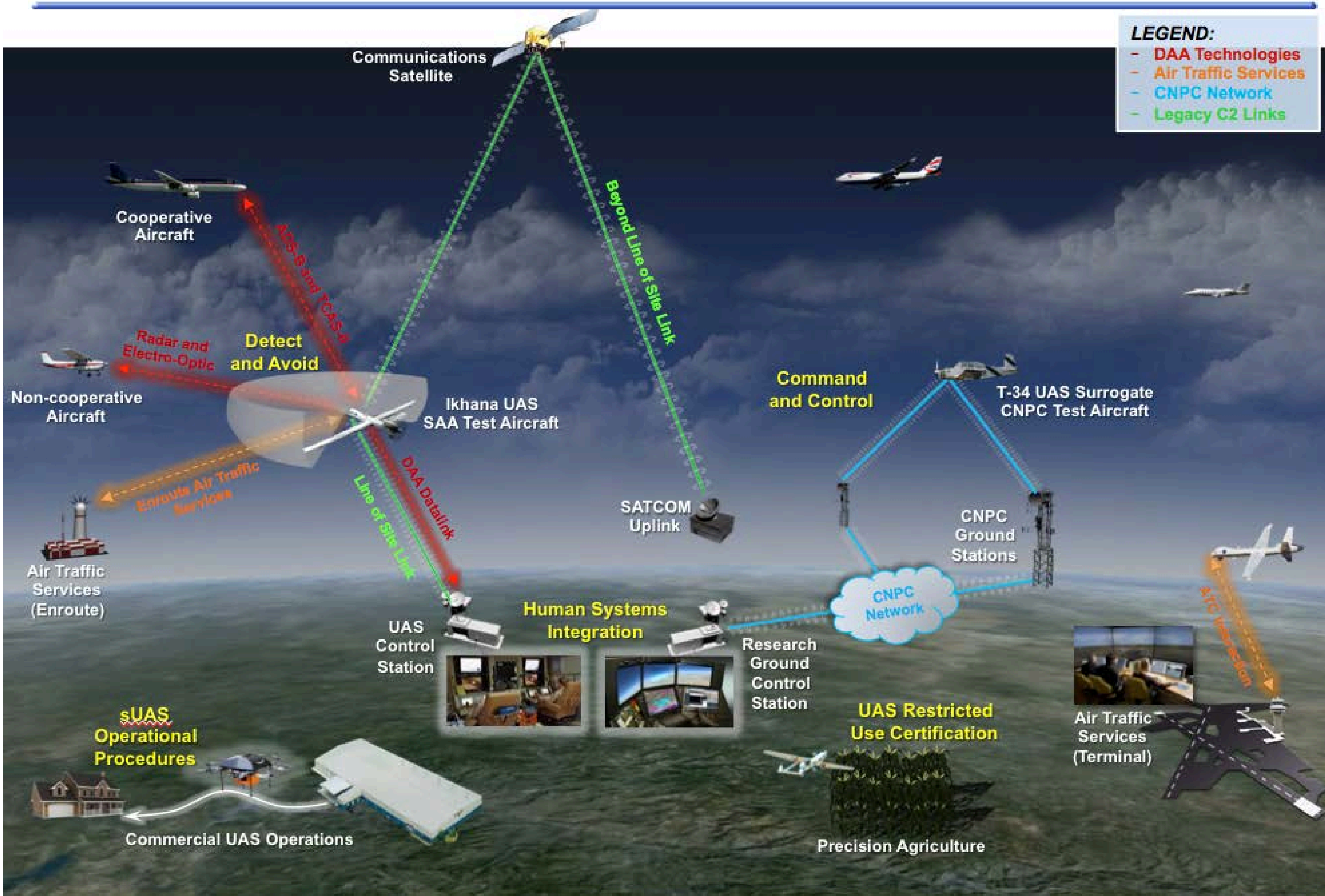
Integrated Test and Evaluation Capstone Demonstration

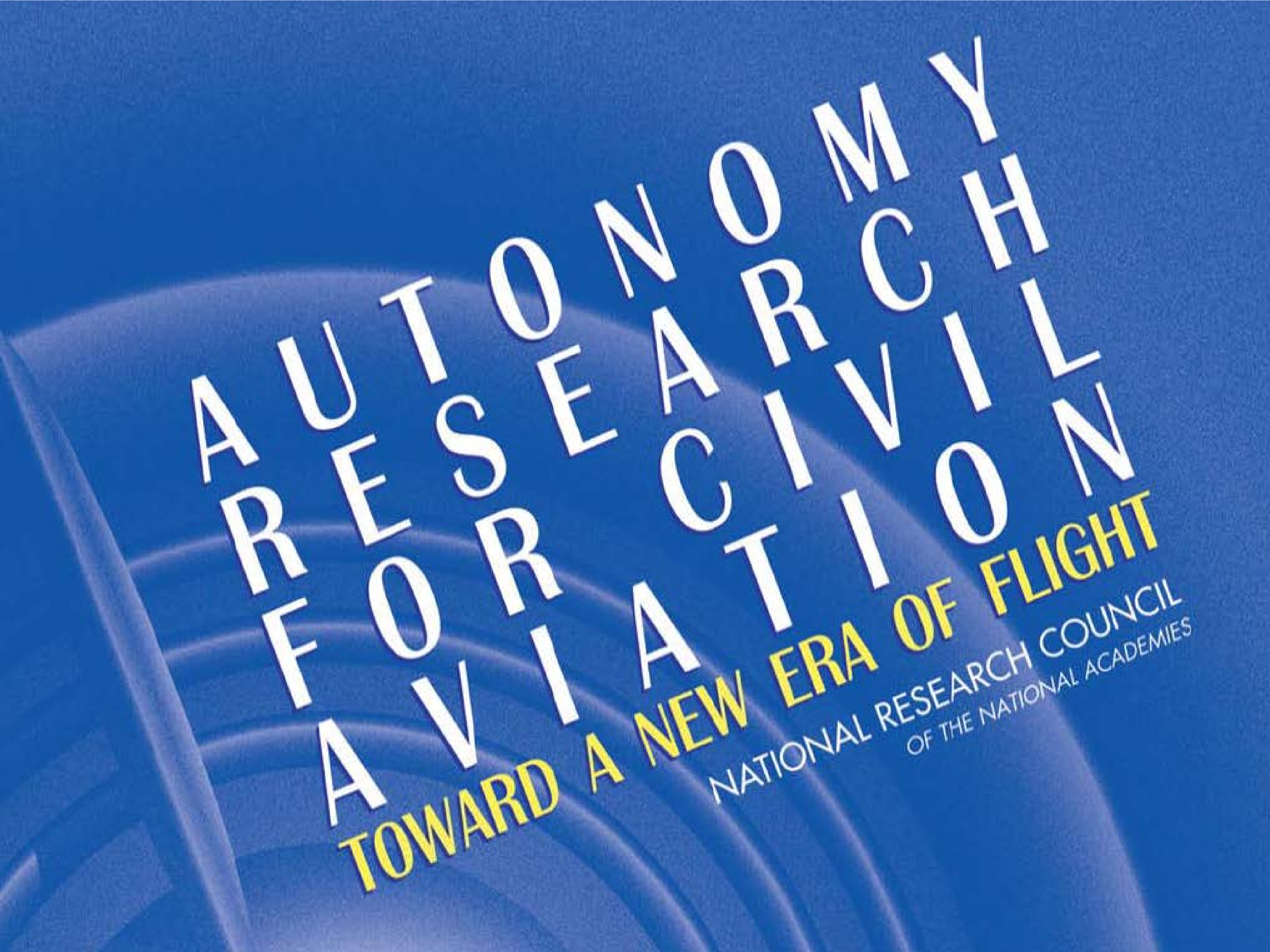


Capstone Description	
Purpose	• Showcase the technologies developed on the Project, specifically: Sense and Avoid, Command and Control, and Human Systems Integration in a relevant test environment • Increase public confidence in UAS
Approach	• Demonstrate the RTCA SC-228 Phase 1 MOPS (i.e. conduct UAS operations to/from Class A, through Class E, Class D, and possibly Class G) • Example: Flights conducted to and from dual use airports within Class D airspace and operated in the NAS in partnership with the FAA
Test Duration	April 2016 • 2 flights (3 hour flights)
Tech Transfer	• These are flight demonstrations and are not needed for data gathering
Project Benefit	• Provides opportunities for partnering with other NASA Mission Directorates (Science Mission Directorate), industry, and academia

The UAS in the NAS capstone demonstration test is the culmination of a progressively complex series of human in the loop simulations and flight tests from June 2014 to April 2016

UAS-NAS Project Operational View




AUTONOMY
RESEARCH
FOR CIVIL
AVIATION
TOWARD A NEW ERA OF FLIGHT
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Vision for Increasingly Autonomous Aircraft and Ground Systems

- New or improved capabilities
  - Function more safely, reliably, and efficiently
  - Expanded array of missions
  - Constrained only by technological limitations and acceptable margins of risk and cost
- Mix of crewed and unmanned aircraft in shared airspace
- ATM systems with distributed responsibilities and authorities
- Designed to minimize failure modes
  - Individual systems
  - NAS as a whole

Key Challenge

- “How can we assure that advanced IA systems—especially those systems that rely on adaptive/nondeterministic software—will enhance rather than diminish the safety and reliability of the NAS?”
  - Certification Process
  - Decision-Making by Adaptive/Nondeterministic Systems
  - Trust in Adaptive/Nondeterministic Systems
  - Verification and Validation

National Research Agenda

Agencies and organizations in government, industry, and academia that are involved in research, development, manufacture, certification, and regulation of IA technologies and systems should execute a national research agenda in autonomy that includes the following high-priority research projects, with the first four being the most urgent and the most difficult:

National Research Agenda (continued)

- Behavior of Adaptive/Nondeterministic Systems
- Operation without Continuous Human Oversight
- Modeling and Simulation
- Verification, Validation, and Certification

- Nontraditional Methodologies and Technologies

- Roles of Personnel and Systems
- Safety and Efficiency
- Stakeholder Trust

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Most Urgent and Most Difficult High-Priority Research Projects

- **Behavior of Adaptive/Nondeterministic Systems**

  Develop methodologies to characterize and bound the behavior of adaptive/nondeterministic systems over their complete life cycle.
- **Operation without Continuous Human Oversight**

  Develop the system architectures and technologies that would enable increasingly sophisticated IA systems and unmanned aircraft to operate for extended periods of time without real-time human cognizance and control.
- **Modeling and Simulation**

  Develop the theoretical basis and methodologies for using modeling and simulation to accelerate the development and maturation of advanced IA systems and aircraft.
- **Verification, Validation, and Certification**

  Develop standards and processes for the verification, validation, and certification of IA systems, and determine their implications for design.

NRC Study Findings

Finding. *Barriers*. There are many substantial barriers to the increased use of autonomy in civil aviation systems and aircraft:

- Technology Barriers
  - Communications and data acquisition
  - Cyberphysical security
  - Diversity of aircraft
  - Human-machine integration
  - Decision making by adaptive / nondeterministic systems
  - Sensing, perception, and cognition
  - System complexity and resilience
  - Verification and validation
- Regulation and Certification Barriers
  - Airspace access for unmanned aircraft
  - Certification process
  - Equivalent level of safety
  - Trust in adaptive/nondeterministic IA systems
- Additional Barriers
  - Legal issues and
  - Social issues

NRC Study Findings (cont.)

- **Potential Benefits and Risks**

The intensity and extent of autonomy-related research, development, implementation, and operations in the civil aviation sector suggest that there are several potential benefits to increased autonomy for civil aviation. These benefits include but are not limited to improved safety and reliability, reduced acquisition and operational costs, and expanded operational capabilities. However, the extent to which these benefits are realized will be greatly dependent on the degree to which the barriers that have been identified are overcome, the extent to which military expertise and systems can be leveraged, and the extent to which government and nongovernment efforts are coordinated.

- **Development of New Regulations**

As with the previous introduction of significantly new technologies, such as fly by wire and composite materials, the FAA will need to develop technical competency in IA systems and issue new guidance material and regulations to enable safe operation of all classes and types of IA systems.